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water action, and I cannot believe that the banded region composed of sand heavily mixed with clay could have been laid down in any other way than those just below. Certainly no wind action can ever be held responsible for such level and uniform deposits over such an area, but it might rather be explained by a change in level affecting the velocity of the current—in fact, I believe the existence of this bed can be explained only in this way.”

G. FREDERICK WRIGHT.

OBERLIN, September 20, 1897.

PROFESSOR RUDOLPH HEIDENHAIN.

THE announcement of the death of Professor Rudolph Heidenhain, though not entirely unexpected, will call forth in physiological circles a note of deepest regret. It brings to memory the names of Brücke, Helmholtz, Karl Ludwig and Emil DuBois-Reymond, members of that coterie of brilliant scientists whose unusual ability for many years attracted to the German laboratories students of medicine from every part of the civilized world. And with these names are largely associated the remarkable transformation and progress which physiological science has experienced since the days of Johannes Müller.

Rudolph Peter Heinrich Heidenhain was sixty-three years of age at the time of his death, having been born Marienwerder, January 29, 1834. The elder Heidenhain was a physician, and it was not strange that the young man should inherit an enthusiasm for the natural sciences; it is told, in fact, that his interest in the work to which his life was devoted was early aroused by the reading of Volkmann's 'Haemodynamik,' which had just been added to the father's library. Heidenhain pursued the usual university medical studies at Königsberg, Halle and Berlin, receiving his degree at the latter place in 1854 with a dissertation entitled 'De nervis

organisque centralibus cordis cordiumque ranae lymphaticorum.' As assistant to DuBois-Reymond, the following three years were devoted to investigations in muscle physiology, a series of studies being published in 1856. In 1857 Heidenhain qualified at Halle as 'Privatdocent' in physiology, with a thesis entitled 'Disquisitiones criticae et experimentae de sanguinis quantitate in mammalium corporis exstantis'; two years afterward, in 1859, at the early age of twenty-five, he accepted the chair of physiology and histology at Breslau in Silesia, a position which he occupied until his death. Heidenhain obtained many official distinctions during his academic career, and among these the Harveian medal with which he seemed especially pleased; he was a member of numerous learned societies, and for many years enjoyed the title of 'Geheimer Medicinalrat.'

The advent of Heidenhain to Breslau and to the institution in which, years before, Purkinje had been active, was followed by a series of physiological researches continued almost uninterruptedly until the past year. These contributions have been marked not alone by the originality with which the subjects have been treated, but especially by a deep insight into the problems presented and a thoroughness of investigation and devotion of energy as untiring as it was characteristic. The results of these labors have had so important an influence in determining certain chapters of physiology as taught to-day that it may, perhaps, be permitted to present a few fragments of Heidenhain's work and to indicate their bearing.

In 1864 appeared the well known monograph on 'Mechanische Leistung, Wärmeentwicklung und Stoffumsatz bei der Muskelthätigkeit.' Helmholtz had shown that the tetanic contractions of a muscle, when continued for some minutes, are attended by a production of heat, but it re-

mained for Heidenhain to demonstrate a rise of temperature amounting to 0.003–0.005°C. with each individual contraction. He discovered the fact that the amount of heat evolved by a muscle in contraction increases with its tension; and in the demonstration that a muscle which contracts without doing external work gives off more heat than does the working muscle on contraction, the principle of the conservation of energy was illustrated by a significant experiment.

To the student of physiology the muscle studies briefly referred to may seem to bear little, if any, relation to Heidenhain's later investigations on the secretory processes in the organism. There was, however, a single great problem which gave the impetus to most of the physiologist's work. "I have endeavored all my life," he once remarked to the writer, "to learn something of the processes which go on in the living cells of the body. In my earlier studies I selected the muscle cells because of their large size. But I soon found that I could not reach the desired end by this means and accordingly I turned to the secreting glands, where I might better observe the entire cells under the microscope. Thus I have been carried farther and farther." Heidenhain's researches on the secretory processes have become classic, and his masterly volume on '*Absonderungsvorgänge*' published in 1883 in Hermann's *Handbuch der Physiologie* will remain as a permanent contribution to physiological literature. The experimental researches which form the basis for these chapters, and in which Heidenhain enjoyed the assistance of a considerable number of co-workers in his laboratory, appeared in large part in the *Studien aus dem physiolog. Institut zu Breslau*, I.–IV., 1861–1868; in *Pflüger's Archiv für Physiologie*, and in *Schultze's Archiv für Mikroskopische Anatomie*.

The tendency of physiological research

at about the middle of the century had been in the direction of a distinctly mechanical theory of the secretory processes in which the physical forces resulting in filtration and diffusion were called upon to explain the known phenomena. The prevalent impression was in good measure due to the brilliant teachings of men like Brücke and Ludwig, although even the latter appreciated many of the difficulties which this aspect presented. It was left for Heidenhain to emphasize the inadequacy of any universal application of the current principles of physics and chemistry to satisfy the problems presented in the secretory functions. He insisted, first of all, on enquiring into the specific changes which take place in the individual organs incidental to their activity; and here again we discover the fundamental notion which was the keynote to Heidenhain's work, namely, the desire to investigate the ultimate seat of physiological changes, as he expressed it: "*Das Wesen der lebenden Zelle die überall in ursprünglich einfacher oder differenzirter Gestalt die Vermittlerin und Trägerin des Geschehens ist.*"* In expanding these ideas Heidenhain has been occasionally misunderstood, or unjustly accused of a belief in some 'vital' forces which transcend the possibilities of natural science. Indeed, I cannot refrain from referring to this fact, which always aroused regret in him; for to one who is familiar with his work nothing can seem more unjustified than this suspicion. No scientist of to-day will deny that the processes which go on in the living cells, that diffusion through a living membrane, is quite a different thing from the processes which can be provoked in these same elements after their death. This, however, does not imply the existence of other forces than the chemical and physical ones which continually manifest themselves in the inorganic world. It merely

*Hermann's *Handbuch der Physiologie*, V., 11.

indicates that our knowledge of how these forces are exerted and how the energy of the cell is transformed is hypothetical or wanting; and not until this deficiency is made up can the physiological experiment be interpreted in simple physico-chemical terms. This was Heidenhain's teaching.

The study of the secretion of the bile early claimed the attention of Heidenhain and his pupils. Besides contributing valuable data on the composition of this fluid and the conditions modifying its discharge from the liver, he made comparative measurements of the pressure under which the bile is secreted and the pressure in a branch of the superior mesenteric vein. In finding the bile pressure invariably twice as high as the blood pressure in the portal vein, he demonstrated for the bile, as Karl Ludwig had done in 1858 for the saliva, that secretion is not a mere act of filtration and thus a mechanical result of blood pressure.

The year 1866 marked the beginning of a series of papers which have contributed more than all others to bring renown to the Breslau physiologist and which mark a distinct advance in physiological knowledge. I refer to the brilliant researches on the salivary, gastric, pancreatic and other glands, in which physiological experiment was successfully combined with histological investigation. The facts discovered have been verified by numerous observers and are familiar to every biologist. Here was shown for the first time that in the secreting glands structural changes go on hand in hand with functional processes. With characteristic patience and thoroughness the various glands were made the subject of an exhaustive study and each new field afforded new problems and new results. For the salivary glands it was shown that the production of specific constituents and the secretion of water are more or less independent processes and thus the idea of distinct trophic and secretory nerves was intro-

duced into physiology. For the pancreas, too, Heidenhain indicated indirectly the existence of specific secretory fibres, which Pawlow has since directly proved. The distinction between serous and mucous glands was also pointed out on the basis of structural, chemical and functional differences.

In his studies on gastric and pancreatic secretion Heidenhain pursued with success the plan which had been found valuable in the case of the salivary glands, and we owe our knowledge of the minute structure of these organs during rest and activity in large part to the labors of this investigator. The fundus and pyloric fistulæ are examples of the valuable methods of research developed by him. Almost simultaneously with Rollet he announced the distinction between the central and parietal gastric cells; his discovery, in 1875, of the so-called 'zymogen' of the proteolytic enzyme of the pancreas has been followed by announcements of precursors for other ferments and has added a new idea to the theory of secretion.

Contrary to the older theory of Bowman, Ludwig had taught that the urine is excreted entirely through the epithelium of the Malpighian capsule, the fluid being eliminated in consequence of purely mechanical filtration, and undergoing a subsequent concentration by the diffusion of water into the lymph spaces surrounding the kidney tubules. Heidenhain's experiments first demonstrated conclusively that the epithelial cells of these tubules take a prominent part in renal secretion. He did not fail to note, at the same time, the close dependence of secretory activity upon blood flow, *i. e.*, upon material for cellular work and upon the presence of oxygen; thus was emphasized the teleological significance of Claude Bernard's discovery that the blood vessels of secreting glands are greatly dilated during glandular activity.

The researches to which the later years of Heidenhain's life were devoted followed

in the course prepared for them by the earlier investigations. In several comprehensive and valuable papers on the histology and physiology of the intestine the inadequacy of osmotic forces to accomplish the work of absorption under many conditions is experimentally shown, the methods of the newer physical chemistry being drawn upon to yield results in a new field. Simple physical forces were supplemented by 'physiological' processes and the seat of these was assigned to the living epithelial cells. The researches on the formation of lymph which have appeared from the Breslau institute in recent years have opened up a broad field of inquiry that, together with the problems of absorption and transudation, is interesting physiologists to-day as perhaps few other themes are. Nowhere in Heidenhain's hypotheses have simple physical factors been excluded; but the difficulty or inadequacy of the latter in accounting for all the facts known is made apparent. And remembering the many differences of opinion that have arisen, let me quote the words of Professor Michael Foster: "In the controversy thus arisen, the last word has, perhaps, not yet been said, but whether we tend at present to side with Heidenhain, who has continued into the past thirteen years the brilliant labours which were, perhaps, the distinguishing features of physiological progress in preceding periods * * * or whether we are inclined to join those who hold different views, we may all agree in saying that we have, in 1897, distinctly clearer ideas of why secretion gathers in an alveolus or lymph in a lymph space than we had in 1884."*

The preceding must suffice in this place to indicate some of the advances which physiology owes to Heidenhain. If to these is added the mention of his researches on

the tonic contractions of sphincter muscles, on the heart and the nervous system, on hypnotism, etc., one cannot fail to be impressed by the broadness of the man. As a scientific writer his style is interesting and convincingly logical. His two monographs in defence of vivisection* have been widely circulated. As a teacher Heidenhain enjoyed unusual success. His lectures were remarkable for the lucid treatment of every department of physiology and histology, and few physiologists, I venture to add, were so liberal in their demonstrations. With every chapter at once made historical as well as critical, and giving evidence of a very wide acquaintance at first hands with the literature of the subject, these lectures would form an admirable text-book with which few of those now used on the Continent could favorably compare. The modest equipment of the old laboratory formed a striking contrast to the splendid results it yielded at the hands of a master.

Heidenhain's home life was charming and the reception within the family circle always cordial. To one associated with him in his work, nothing was more impressive than the man's intense devotion to his science. The indifferent student could expect little sympathy from Heidenhain; but no attention was spared, no effort too great in behalf of the individuals who won favor in the Breslau institute. Logical argument and unbiased observation characterized Heidenhain's presence in the laboratory. His thoughts continually wandered into the realm of unanswered problems, and more than once in recent years did he express the regret that the days still left must be brief, at most, for the tasks awaiting completion. These fruitful labors have, indeed, been ended too soon.

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* Address to the Physiological Section, British Association for the Advancement of Science, Toronto, 1897.

* 'Die Vivisection im Dienste der Heilkunde,' 1879, and 'Die Vivisection,' 1884.